The Canadian Land Data Assimilation System: Current and Upcoming Projects

Stéphane Bélair[1], Bernard Bilodeau[1], Marco Carrera[1], Natacha Bernier[1], Chris Derksen[2], Douglas Chan[3]

1Meteorological Research Division, Environment Canada, Dorval, QC, Canada
2Climate Research Division, Environment Canada, Downsview, ON, Canada
3Climate Chemistry Measurements and Research, Environment Canada, Downsview, ON, Canada

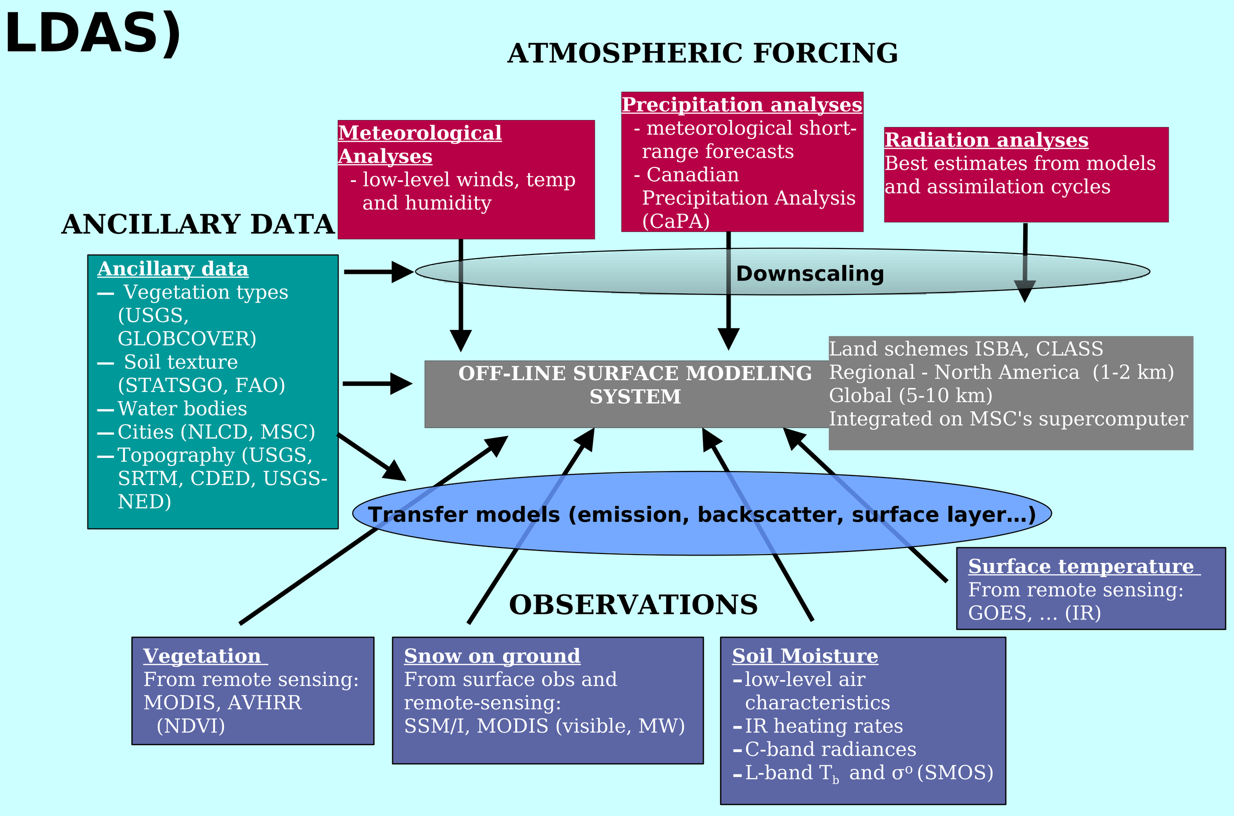
The Canadian Land Data Assimilation System (CaLDAS)

Characteristics and initial conditions of the land surface are of crucial importance in environmental modeling systems (e.g., numerical weather prediction, hydrology, agriculture, forests) – indeed, they are as important as the models themselves.
A special effort is currently being made at Environment Canada to specify as best as possible the land surface variables and chacteristics for ***snow, soil moisture*** *and* ***vegetation.***

In Environment Canada's ***current*** operational systems:

- ***Snow depth*** *is analyzed using observations from in-situ surface stations;*
- ***Soil moisture*** is obtained by assimilating screen-level air temperature and humidity, using an optimal interpolation (OI) technique;
- ***Vegetation*** characteristics (LAI, coverage fraction) are specified from static land use / land cover databases.

A new system, called the **Ca**nadian **L**and **D**ata **A**ssimilation **S**ystem (**CaLDAS**), is currently being developed to improve the land surface characteristics used in our environmental prediction system. The general structure of this system is given on the right:

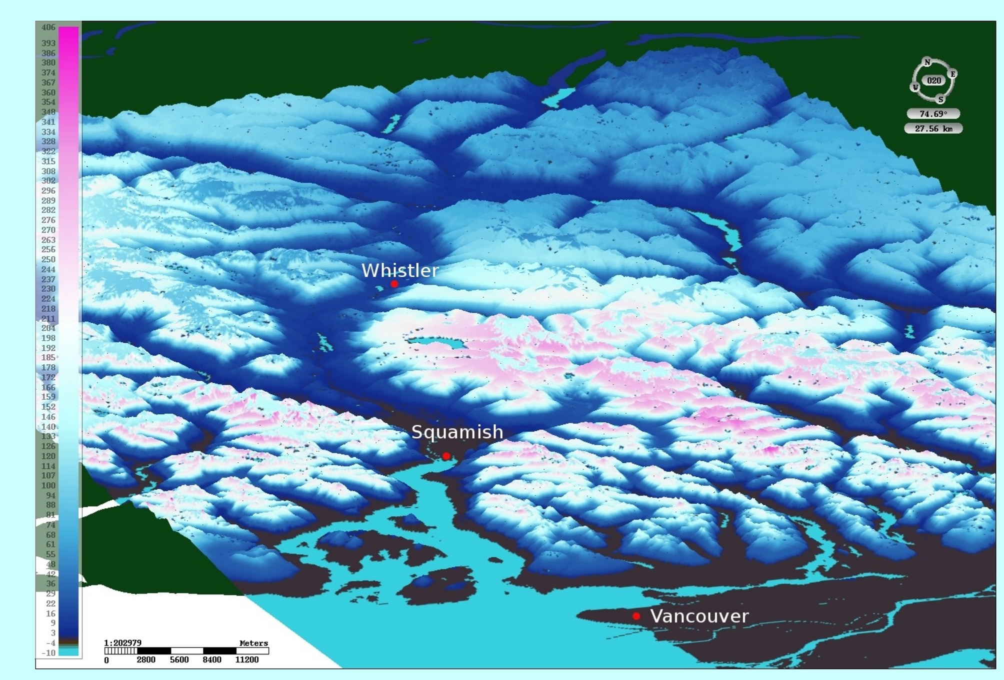


High Resolution Background (First guess)

Due to its low computational cost, it is possible (and even preferable) to integrate land surface processes with grid sizes smaller than those typically used in atmospheric models.

Using this approach, the assimilation system benefits from the very high-resolution information currently available for important land surface characteristics such as orography, slope and land use / land cover.

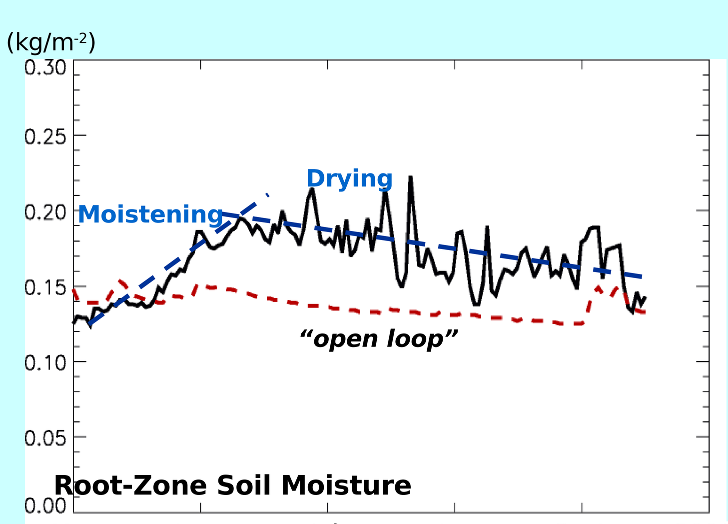
Another advantage of producing a high-resolution first guess in CaLDAS is related to the downscaling processes that can be used for the atmospheric forcing (wind, air temperature and humidity, precipitation). This leads to a more realistic evolution of land surface variables. For example, snow in complex terrain is better represented with this adapted atmospheric forcing, as shown in the figure on the right.



Snow depth (cm) over southwestern British Columbia obtained from an open-loop experiment with the 100-m external land surface system (valid at 0000 UTC 1 Dec 2008).

Soil moisture

As can be seen in the figure below, obtained from Environment Canada's current operational version of CaLDAS, assimilation of near-surface temperature and relative humidity can significantly modify the seasonal evolution of soil moisture.



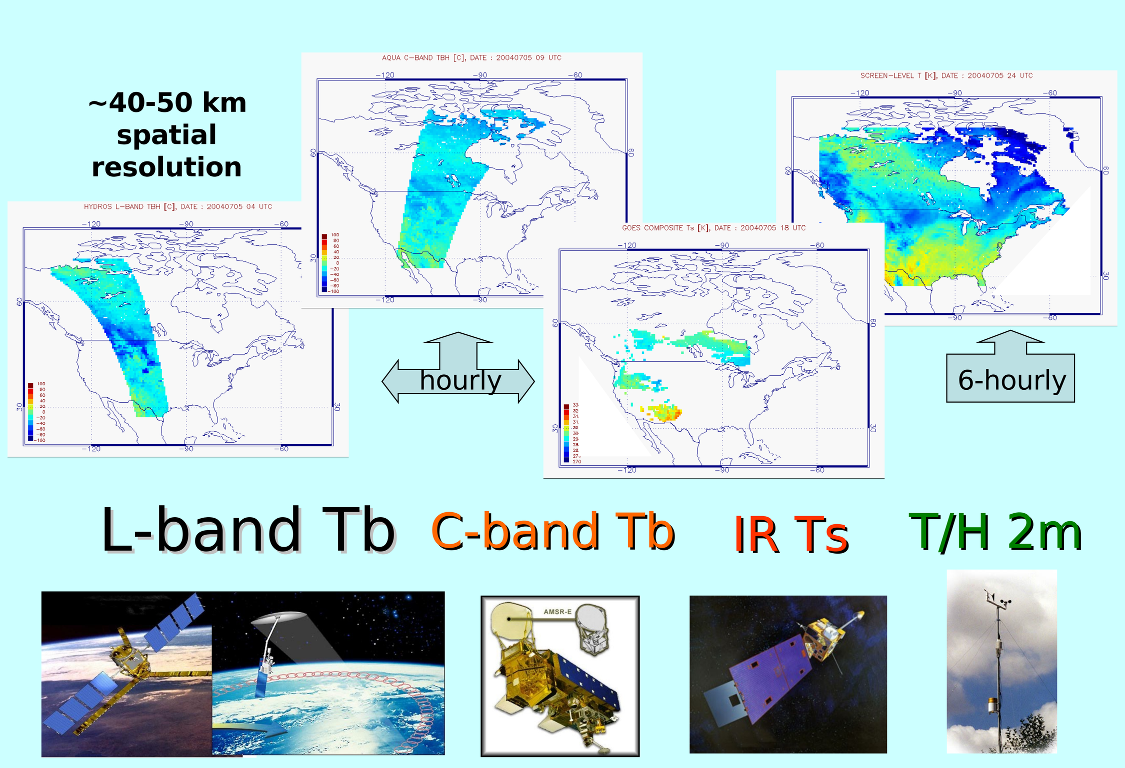
EC's operational sequential assimilation for spring-summer 2006 over the South Saskatchewan River basin is compared to open-loop experiment. The impact of assimilating screen-level observations is important.

Until recently, the benefits of improving the soil moisture analyses were mainly evaluated for numerical weather prediction, in which significant impact were noted on short and medium-range forecasts.

But with a widening of Environment Canada's mandate, direct evaluation of soil moisture against field measurements are becoming important, in view of increasing the applicability of CaLDAS to hydrology, agriculture and other fields of study.

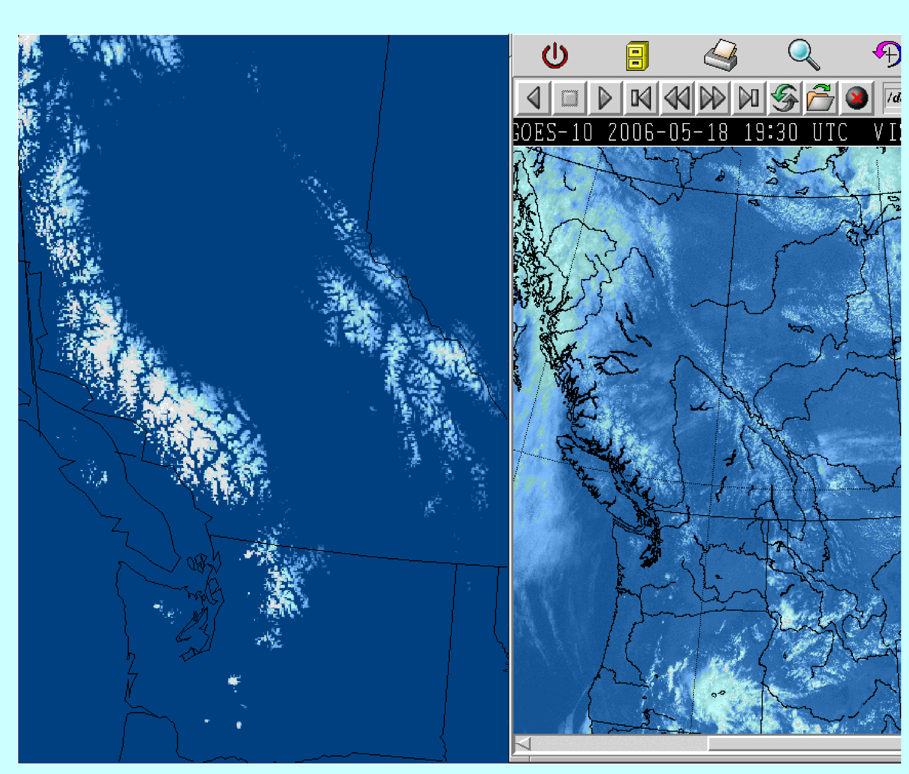
For these reasons, space-based remote sensing observations are currently being included in CaLDAS. Focus is on the inclusion of passive L-band data that will soon become available with ESA's Soil Moisture and Ocean Salinity (SMOS) mission, and later from NASA's Soil Moisture Active and Passive (SMAP) mission.

But, as shown in the figure below, other types of remote sensing data are being considered, such as thermal infrared and C-band data.



Snow

In Environment Canada's current systems, observations from surface stations are assimilated to provide initial conditions for snow depth. This assimilation is performed for the global (33 km), continental (15 km), and local (2.5 km) atmospheric systems. The figure below shows an example of the snow depth analysis over Canada's West coast, for the local 2.5-km system. This analysis benefits from the adaptation of the temperature forcing for the high-resolution orography, and is more realistic than the 33-km and 15-km analyses (especially in mountainous regions).



2.5-km snow depth analysis (left) and VIS satellite image (right) valid at 1830 UTC 18 May 2006

To improve the assimilation of terrestrial snow, particular emphasis has been put on the production of a high-resolution first guess, which allows a more realistic representation of snow in complex terrain.

In addition, the inclusion of space-based remote sensing data in CaLDAS will soon be examined. It will feature:

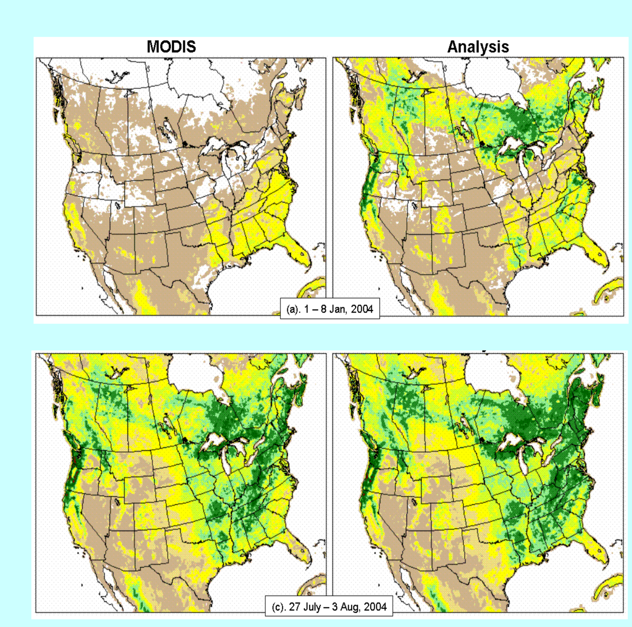
i) high-resolution visible data from space-based remote sensing for the specification of fractional coverage of snow;

ii) lower resolution microwave data for snow water equivalent (SWE).

Vegetation

Vegetation characteristics (leaf area index, fractional coverage) are currently specified in the Meteorological Service of Canada's operational system using land use / land cover databases. The vegetation characteristics are obtained via look-up tables with pre-established correspondence between the dominant vegetation type and vegetation characteristics.

Some work has been recently done at Environment Canada to assimilate MODIS data in order to speficy vegetation characteristics, based on an OI scheme. Although simple, this approach provides more realistic estimates of LAI.



Land cover databases do not provide information on LAI (usually specified using a look-up table). LAI is important for evapo-transpiration. Using the LAI analysis from MODIS (or other instruments) could reduce an important source of errors.

In this simple technique, the first guess is based on a climatology obtained from MODIS LAI data. In collaboration with partners at the Climate Research Division, we are currently implementing Biome-BGC to provide the first guess for the assimilation. This model represents the biological and physical processes controling carbon, water, and nitrogen dynamics in terrestrial ecosystems.